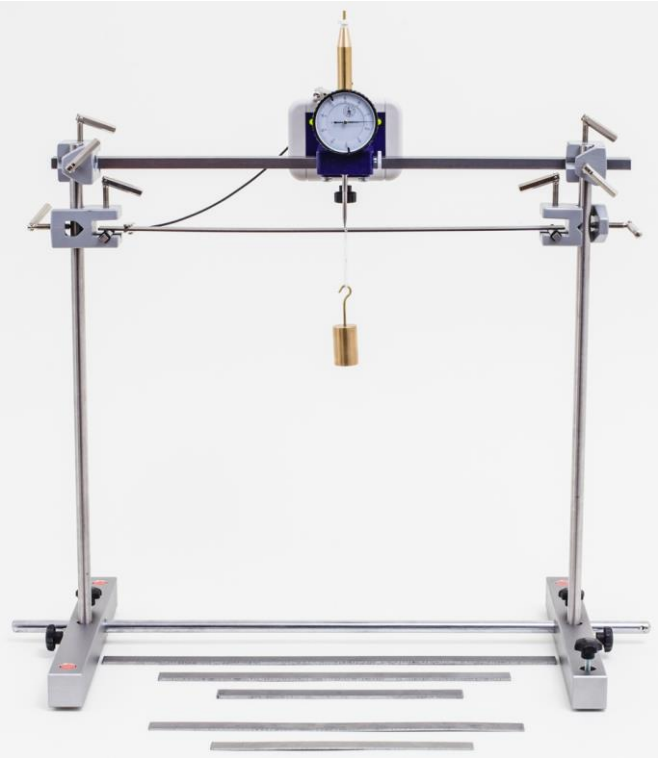
Equipment Set for Modulus of Elasticity 1018527

Instruction manual

05/16 TL/UD



1. Safety instructions

Safe operation of this equipment is assured as long as it is used as stipulated. Safety cannot be guaranteed, however, if the equipment is used incorrectly or carelessly.

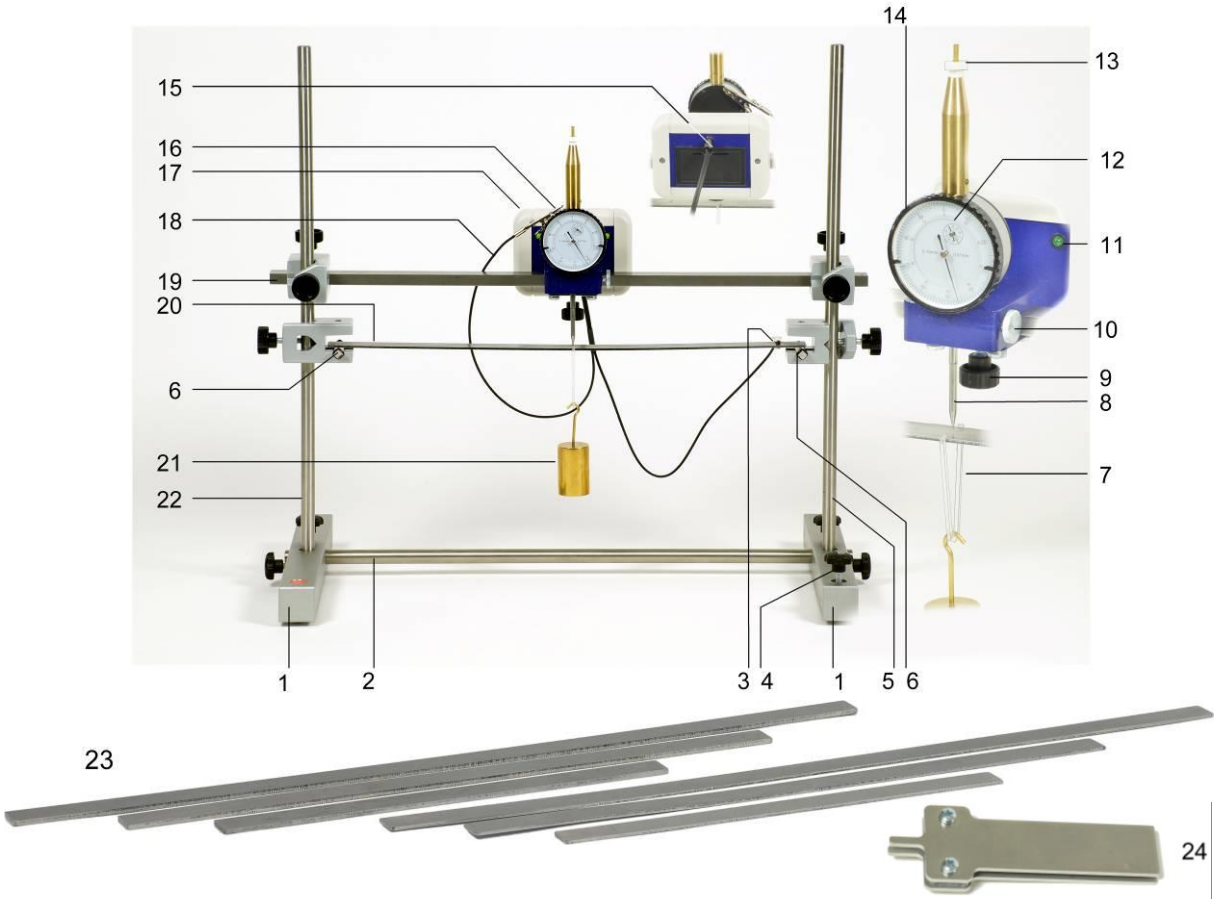
If there is any likelihood that the equipment can no longer be operated without hazard (e.g. if there is visible damage), it must immediately be put out of use.

- The equipment may only be used in dry rooms.
- Do not apply any external voltage to the 3.5-mm jack socket of the bending gauge.
- Only use the equipment with the supplied 9-V battery or other of the same model (6F22).

If the horizontal bar slips out of the universal clamp with the bending gauge attached, the gauge may be irreversibly damaged.

- When inserting or removing the horizontal bar with the bending gauge attached, make sure that the bar does not slip out of the universal clamp and fall down.
- Before inserting the horizontal bar with the bending gauge attached or after removing it, always lay it down in such a way that the plastic housing of the gauge is lying on its back. Unplug the lead for the measuring probe contact from the 3.5-mm jack socket beforehand.

2. Equipment



1 Rectangular base
2 Base strut
3 Clamp for material sample
4 Levelling screw
5 Vertical rod, right
6 Knife-edge bearing
7 Clamp for weight
8 Measuring probe
9 Securing screw for bending gauge unit
10 Securing screw for bending gauge
11 LED display for measuring probe contact
12 Bending gauge
13 Height adjustment screw for measuring probe
14 Scale ring
15 3.5-mm jack socket for lead to measuring probe contact
16 Clamp for bending gauge
17 Bending gauge unit
18 Lead to measuring probe contact
19 Horizontal bar
20 Material sample
21 Weight, 5x 50 g
22 Vertical rod, left
23 Material samples (6x)
24 Clamp

3. Material samples

Width:	Thickness:	Lengths:
15 mm	2 mm	215 mm, 315 mm, 415 mm
15 mm	3 mm	215 mm, 315 mm, 415 mm

Material: Steel

4. Technical data

Battery for bending gauge unit:	9 V, 6F22
Measuring range of gauge:	0 – 10 mm
Resolution of gauge:	0.01 mm
Dimensions:	550x280x500 mm approx.
Weight:	5.5 kg approx.

5. Description

The equipment set for studying the modulus of elasticity comprises six flat steel rods, 15 mm wide but with different thickness and lengths, as well as a bending gauge unit, a horizontal bar with a stand, two knife-edge bearings, a clamp and two weights with their own clamps.

The equipment set allows you to investigate elastic deformation of the flat rods and determine the modulus of elasticity for each of them. The bending gauge makes it possible to determine the degree of bending of electrically conducting material samples without needing to take into account the load characteristic of the gauge itself. The bending gauge unit makes electrical contact with the material sample in such a way that it can determine with high sensitivity how the measuring probe is resting on the sample and display it with the help of two LEDs. In this way almost zero load is applied on account of the measuring equipment. The way the material deforms when a weight is suspended from it can be measured to an accuracy of 0.01 mm and the modulus of elasticity can then be calculated from this reading.

It is possible to do measurements with the material samples supported on both sides or on one side only.

6. Set-up

6.1 Material sample supported on both sides

Fig. 1: Experiment set-up for material samples supported on both sides

- First assemble the stand with the two rectangular base pieces, the base strut, the two vertical rods and four universal clamps as shown in Fig. 1. Secure the two universal clamps holding the horizontal bar with the bending gauge unit attached at the same height on the respective vertical rod. The two universal clamps to hold the material sample should be about 15 mm below them. Take note of the alignment of the universal clamps in Fig. 1.
- Fit one knife-edge bearing into each of the universal clamps to support the material sample. Secure them in place with rubber rings.
- Set the rectangular base pieces apart in such a way that the separation between the knife-edge bearings matches the *effective* length of the material sample to be measured, i.e. 200 mm, 300 mm or 400 mm.
- Move the bending gauge unit over the horizontal bar and attach it in the middle of the bar with the help of the gauge unit's securing screw.
- Secure the horizontal bar with the gauge unit attached into the uppermost pair of universal clamps (observe the safety instructions in section 1) in such a way that the tip of the measuring probe is located precisely in the centre between the knife-edge bearings.
- Adjust the height of the measuring probe so that it is centred on the bar. Adjust the height of the probe up or down using the adjustment screw in such a way that the threaded rod protrudes about 14 mm above the height adjustment screw.
- Lift up the measuring probe and place the material sample to be measured onto the knife-edge bearings in such a way that it is horizontal and symmetrical but with the ends not touching the universal clamps. Carefully lower the measuring probe onto the material sample. If the sample is not exactly horizontal, correct the positions of the universal clamps by moving them along the vertical rods.
- If the sample is at a slight angle, e.g. due to some unevenness in the surface on which the apparatus is set up, use the levelling screw to compensate for this.
- Plug the 3.5-mm jack plug on the connecting lead for the bending gauge contact into the 3.5-mm socket on the rear of the bending gauge unit. Fix one of the contacts for the lead firmly into place in the terminal provided for the purpose on the gauge and connect the other to the material sample as shown in Fig. 1.

- Use the clamp to suspend a weight from the very centre of the material sample level with the measuring probe.
- Before performing another measurement on a sample bar which is longer or shorter, first remove the horizontal bar with the bending gauge (observing the safety instructions in section 1) and readjust the separation of the rectangular base pieces. Then proceed again as described above.

6.2 Material sample supported on one side

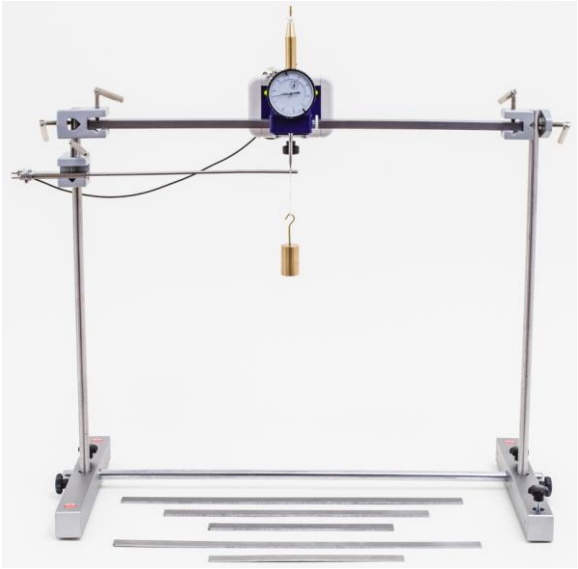


Fig. 2: Experiment set-up for material samples supported on one side.

- Assemble the stand as shown in Fig. 2. Secure the two universal clamps holding the horizontal bar with the bending gauge unit attached at the same height on the respective vertical rod. The single universal clamp needed to hold the material sample at one end should be about 15 mm below them.
- Set the rectangular base pieces apart in such a way that the ends of the horizontal bar are flush with the two universal clamps holding it.
- Move the bending gauge unit along the horizontal bar and secure it in the centre to begin with using the securing screw.
- Secure the horizontal bar with the gauge unit attached into the uppermost pair of universal clamps (observe the safety instructions in section 1).
- Adjust the height of the measuring probe so that it is centred on the bar. Adjust the height of the probe up or down using the adjustment screw in such a way that the threaded rod protrudes about 14 mm above the height adjustment screw.
- Secure the material sample to be measured lengthways in the holding clamp and fit it into the lower universal clamp as shown in Fig. 2. You should lift the measuring probe of the gauge unit and then carefully lower it onto the material sample. Make sure that the jaws of the clamp are flush against the universal clamp on the overhanging end of the sample.
- Undo the securing screw for the gauge unit, lift up the measuring probe and move the unit along the horizontal bar until the measuring probe is a few millimetres from the free hanging end of the material sample.
- Plug the 3.5-mm jack plug on the connecting lead for the bending gauge contact into the 3.5-mm socket on the rear of the bending gauge unit. Fix one of the contacts for the lead firmly into place in the terminal provided for the purpose on the gauge and connect the other to the back of the holding clamp as shown in Fig. 2.
- Suspend a weight from the material sample level with the measuring probe using its own clamp.

Notes:

It may be advisable to dry the material samples at the point where they are contacted by the measuring probe using a kitchen sponge, for example.

Use a 2-m tape measure (1002603) and digital callipers (1002602) to accurately measure the distance between the knife-edge bearings for samples supported at two ends or between the measuring probe and the front edge of the holding clip or between the front end of the holding clip and the tip pf the measuring probe for samples supported at one end only. Write down the values.

7. Operation of gauge

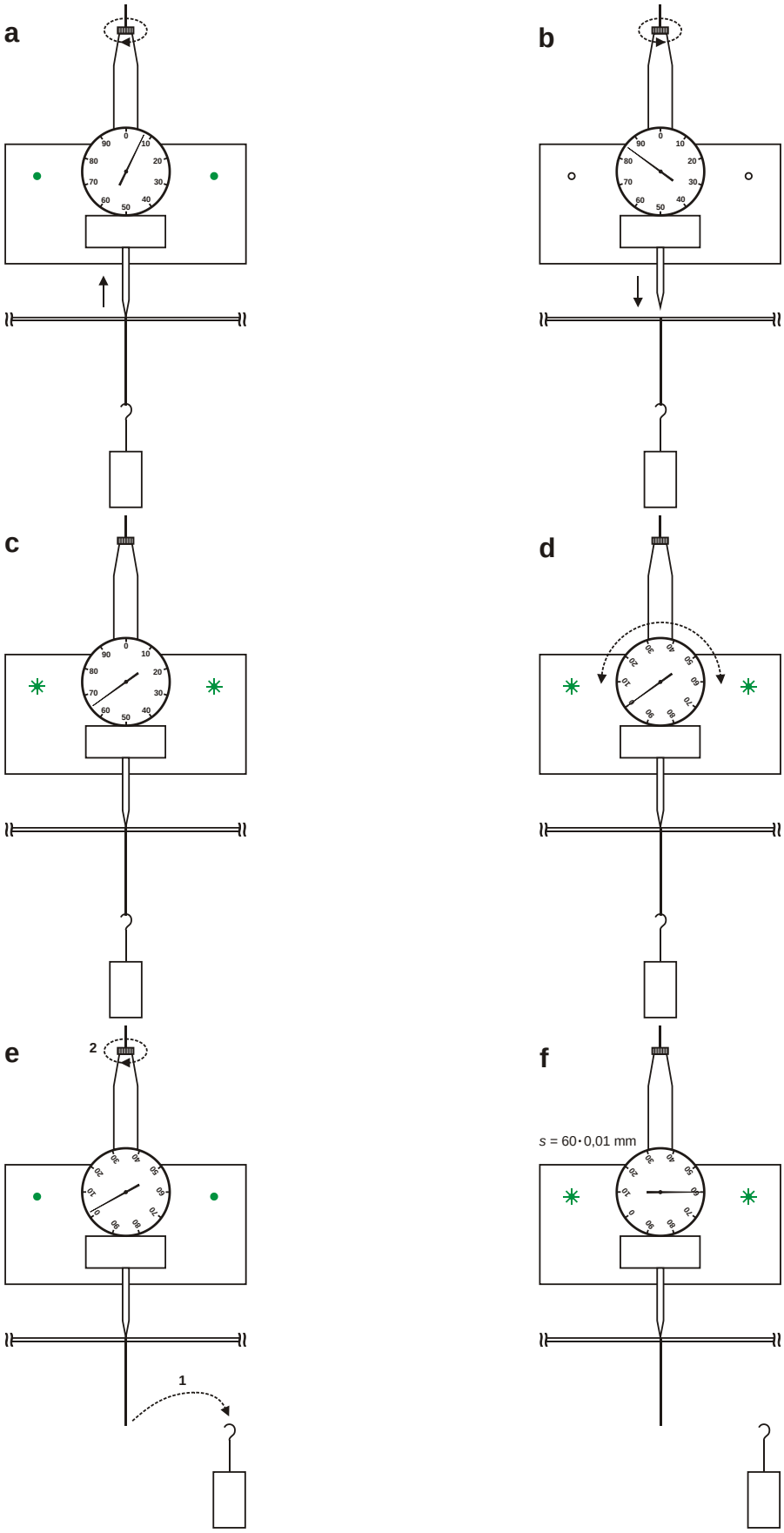


Fig. 3: Operation of gauge.

- First turn the scale ring of the gauge until the zero position on the scale is a 12 o'clock.

Both LEDs on the bending gauge unit will light up when the measuring probe touches the material sample and will go out when the contact is broken.

Note:
When samples 2 mm thick are suspended at one end and a 200-g weight is attached, the bending may be so great that the measuring probe makes no contact even when the height adjustment screw is turned all the way. If this happens, move the clamp holding the material sample slightly closer to the one holding the horizontal bar (so the distance between is about 10 mm).

- If the LEDs are lit when the weight is suspended from the sample, turn the height adjustment screw clockwise until the LEDs start to flicker (Fig. 3a,c).
- If the LEDs are not lit when the weight is suspended from the sample, turn the height adjustment screw anti-clockwise until the LEDs start to flicker (Fig. 3b,c).

Note:
When the LEDs are flickering, it indicates that the measuring probe is contacting the sample but adding almost nothing to the actual load.

Both LEDs work in the same way.

- Turn the scale ring of the gauge until zero coincides with the position of the needle (Fig. 3d).
- Carefully suspend the weight from the clamp (Fig. 3e). The material sample will exert a force pushing the measuring probe back up and, depending on the type of measurement being made (see 6.1 or 6.2), the material sample being used and the mass of the weight, the needle of the gauge will move to a greater or lesser degree from the calibrated zero point. The LEDs will both be permanently on.
- Turn the weight adjustment screw clockwise (Fig. 3e) until the LEDs start flickering again, i.e. until there is no force on the measuring probe again (Fig. 3f). The value indicated on the black scale of the gauge corresponds to the degree of bending of the material sample. Read off this value and write it down. Make sure that the pointer may make one or more full revolutions depending on the material sample and weight suspended from it. Each revolution corresponds to bending by 1 mm and needs to be taken fully into account.
- It may be sensible to carry out the measurement multiple times to obtain an average value.

Note:
The procedure can also be done in reverse, i.e. calibration of the zero point can be done without the weight being suspended and the value read off when it is. In this case the gauge deflects anti-clockwise and the measurement can be read from the red scale of the gauge.

8. Calculation of modulus of elasticity *E*

8.1 Material sample supported at both ends

$$E = \left(\frac{L_2}{d}\right)^3 \cdot \frac{F}{4 \cdot b \cdot s}$$

E: Modulus of elasticity
L_2: Distance between knife edge bearings
d: Thickness of material sample
b: Length of material sample
s: Bending of material sample
F: Weight

$$E = \left(\frac{300\,\text{mm}}{2\,\text{mm}}\right)^3 \cdot \frac{0.1\text{kg} \cdot 9.81\,\frac{\text{m}}{\text{s}^2}}{4 \cdot 15\,\text{mm} \cdot (29 \cdot 0.01\,\text{mm})}$$

$$= 190\,\frac{\text{kN}}{\text{mm}^2} = 190\,\text{GPa}$$

8.2 Material sample supported at one end

$$E = \left(\frac{L_1}{d}\right)^3 \cdot \frac{4 \cdot F}{b \cdot s}$$

L_1: Distance between tip of measuring probe and front of holding clip

$$E = \frac{\left(\frac{244\,\text{mm}}{2\,\text{mm}}\right)^3 \cdot 4 \cdot 0.1\text{kg} \cdot 9.81\,\frac{\text{m}}{\text{s}^2}}{15\,\text{mm} \cdot (2\,\text{mm} + 58 \cdot 0.01\,\text{mm} - 0.024\,\text{mm})}$$

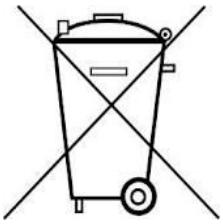
$$= 186\,\frac{\text{kN}}{\text{mm}^2} = 186\,\text{GPa}$$

Note:
For samples supported at one end, higher accuracy can be achieved if the torque acting on the universal clamp is taken into account. 0.01 mm may be subtracted from the reading for each newton of force exerted by the weight and for each 100 mm of effective length of the sample. In the sample measurement above, where L_1 = 244 mm and F = 0.98 N the amount to be subtracted would therefore be 2.44 · 0.98 · 0.01 mm = 0.024 mm.

The values determined by the two methods only disagree by about 2% and are in good agreement with values quoted in tables (190 – 210 GPa depending on the type of steel).

9. Storage, cleaning and disposal

- Keep the equipment in a clean, dry and dust-free place.
- Do not clean the unit with volatile solvents or abrasive cleaners.
- Use a soft, damp cloth to clean it.
- The packaging should be disposed of at local recycling points.
- Should you need to dispose of the equipment itself, never throw it away in normal domestic waste. Local regulations for the disposal of electrical equipment will apply.



- Do not dispose of the battery in the regular household garbage. Follow the local regulations (In Germany: BattG; EU: 2006/66/EG).